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February 12, 1957

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SUBJECT: Contract RD-94
Task Order No. 2

[redacted] 25X1

In accordance with Article 2 of the basic contract, there are forwarded herewith two (2) copies of the Monthly Progress Report for January, 1957 on Task Order No. 2 of RD-94. The report is dated February 11, 1957. This report is UNCLASSIFIED. An additional copy is being held in [redacted] by the project engineer for the use of your personnel while at this location. 25X1

In connection with this monthly progress report, the following information is submitted:

Total expenditures to 12-31-56	$15,068
Outstanding commitments as of 12-31-56	None
Funds remaining as of 12-31-56	$45,248

Very truly yours,

[redacted] 25X1

Assistant Manager
Government Contract Administration

TRR:pah
f-14608
Enclosures

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Monthly Progress Report
January 1957

Task Order No. 2
Contract No. RD-94

Audio Noise Reduction Circuits

The object of this project is to develop a noise reduction circuit suitable for use in separating speech intelligence from a signal containing speech and noise when the speech intelligence is masked by the noise. The proposed method involves a principle which has been used successfully to improve the signal-to-noise ratio in music reproducing or transmission systems[1]. The system used for music contains bandpass filters which pass frequencies over a range of an octave or less. These filters are used at the input and output of a non-linear element. The output of the non-linear elements contain the fundamental, and also harmonics and subharmonics of the fundamental. However, since the pass band of the input and output bandpass filters is no greater than an octave, the harmonics and subharmonics are not transmitted by the system. The function of the non-linear element is to reject all noise signals below a given amplitude or threshold level. The threshold levels of the non-linear devices in each channel can be adjusted so that, in the absence of desired signal, the noise is rejected. When the desired signal is greater than the threshold level the non-linear elements allow the composite signal to pass. Thus, for passages of recorded music, when the music signal is below the noise level in a given frequency channel, the channel is inoperative, and its output is eliminated from the total output. Since the contribution of this channel to the total output would have been only noise, the overall noise level is reduced. When the music signal in a given channel is greater than the noise, the channel conducts and allows the composite signal to pass. Thus a channel conducts only when the desired signal is greater than the

1. H. F. Olson, "Electronics", Dec. 1947.

noise, and rejects when noise alone is present.

In order to apply this method of noise reduction to speech, when the wide band speech signal-to-noise ratio is very low, it is necessary to find frequency regions in which there are times when the speech amplitude is greater than the noise. Although the long time average spectrum of speech is continuous, and similar in shape to the spectrum of room noise,[2] the short time spectrum of various speech sounds contains regions of maximum energy called speech formants[3]. The assumption that this method of noise reduction could be utilized for speech was based upon the belief that it would be possible to find frequency regions in which the amplitude of the speech formants would be greater than the noise a substantial part of the time.

A study has been made to determine what bandwidths are required in order to obtain speech formant amplitudes above the noise when a wide band speech sample is just intelligible in noise. It is known that for noises with a continuous spectrum it is the noise components in the immediate frequency region of the masked tone which contribute to the masking[4]. When a very narrow band of noise is used to mask a pure tone, the masking increases as the bandwidth is increased until a certain bandwidth is reached. After this, as the bandwidth is increased, the amount of masking remains constant. This bandwidth at which the masking reaches a fixed value, is termed the critical bandwidth[5]. The critical bandwidth is a function of frequency. It is different when listening with one or two ears. The critical bandwidth for two ears as a function of frequency is shown by the upper curve of Figure 1. Measurements have been made

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2. H. Fletcher, "Speech and Hearing on Communication", Van Nostrand Co., Inc. NYC 1953 (see figures 61 and 70)

3. Op.cit. chap. 1

4. L. L. Beranek, "The Design of Speech Communication Systems", Proc. IRE, vol. 35, pp.882, Sept. 1947.

5. N. R. French and J. C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds", Jour. Acoust. Soc. Amer. Vol.19, Jan. 1947 (see figure 7)

using filters which were both narrower and wider than the critical bandwidth. Both pure tones and speech mixed with continuous spectrum type noises have been studied. The results of this study show that, for the narrowest permissible bands which can be used to pass speech formants, the number of times the speech formant amplitude in a given band exceeds the noise is small. Also, in these bands, the speech amplitude is never considerably greater than the noise. Since very narrow bandwidths are required to reduce the noise below the signal, the number of bands required to cover the speech spectrum is quite large. There is no satisfactory way of evaluating the effect upon speech intelligence of small contributions from many narrow bands without building a many channeled circuit and evaluating it by making articulation measurements. From the information available from studying a few channels throughout the speech spectrum it seems possible that some improvement in intelligibility can be effected, but this improvement may prove to be small.

In view of the fact that there is no convenient way to evaluate the contributions of a few narrow band channels to speech intelligibility, a complete multi-channel system will be developed in order to determine the effectiveness of this method of improving speech intelligibility in noise. The system under development will contain approximately 80 frequency channels in the frequency range from 700 to 3200 cps. The bandwidths of these channels will be 3 db narrower than the critical bands. The bandwidths of these channels as a function of frequency are shown by the lower curve of Figure 1.

During January, the design of a ten channel prototype circuit has been completed. Eight of these circuits will be required to form an 80 channel noise reducer. The circuit schematic and chassis layout drawings have been completed, and the circuit is now under construction in the model shop. It is planned to complete and test this prototype before the other seven are built. A block diagram of this circuit is shown in Figure 2. The prototype chassis will require a seven inch panel. The total 80 channel noise reducer circuit will be housed in a seven foot relay rack. A view of the planned relay rack is shown in Figure 3. A block diagram of the 80 channel circuit is shown in Figure 4. A schedule of the frequency of each channel and the chassis position is shown in Table I. The approximations which these channels have to the desired curve are shown in Figure 1.

Efforts to purchase special low pass filters for use in its output of each 10 channel circuit, as shown in Figure 2, and obtain delivery in less than three months have been unsuccessful. Therefore, it was deemed necessary to design and construct these low pass filters. The filters for all eight groups have been designed. The one for the prototype chassis is now under construction.

ESR:nan
Feb. 11, 1957

Table I

Band Center, Bandwidth and Chassis

Position of each Channel

Chassis No.	Channel No.	Band Center CPS	Band-width CPS	Low Pass Cut off CPS
	1	700	20	
	2	720	20	
	3	740	20	
	4	760	20	
1	5	780	20	1000
	6	800	20	
	7	820	20	
	8	840	20	
	9	860	20	
	10	880	20	
	11	900	22	
	12	922	22	
	13	944	22	
	14	966	22	
2	15	988	22	1200
	16	1010	22	
	17	1032	22	
	18	1054	22	
	19	1076	22	
	20	1098	22	
	21	1120	24	
	22	1144	24	
	23	1168	24	
	24	1192	24	
3	25	1216	24	1400
	26	1240	24	
	27	1264	24	
	28	1290	26	
	29	1316	26	
	30	1342	26	

Table I (Cont).

Chassis No.	Channel No.	Band Center CPS	Band-width CPS	Low Pass Cut off CPS
	31	1368	26	
	32	1394	26	
	33	1420	26	
	34	1448	28	
4	35	1476	28	1700
	36	1504	28	
	37	1532	28	
	38	1560	28	
	39	1590	30	
	40	1620	30	
	41	1650	30	
	42	1680	30	
	43	1710	30	
	44	1742	32	
	45	1774	32	
5	46	1806	32	2000
	47	1838	32	
	48	1870	32	
	49	1904	34	
	50	1938	34	
	51	1972	34	
	52	2006	34	
	53	2042	36	
	54	2078	36	
6	55	2114	36	2400
	56	2150	36	
	57	2190	40	
	58	2230	40	
	59	2270	40	
	60	2310	40	

Table I (Cont).

Chassis No.	Channel No.	Band Center CPS	Band-width CPS	Low Pass Cut off CPS
7	61	2350	40	2800
	62	2390	40	
	63	2430	40	
	64	2470	40	
	65	2514	44	
	66	2558	44	
	67	2602	44	
	68	2646	44	
	69	2690	44	
	70	2734	44	
8	71	2782	48	3600
	72	2830	48	
	73	2878	48	
	74	2926	48	
	75	2974	48	
	76	3026	52	
	77	3078	52	
	78	3130	52	
	79	3182	52	
	80	3234	52	

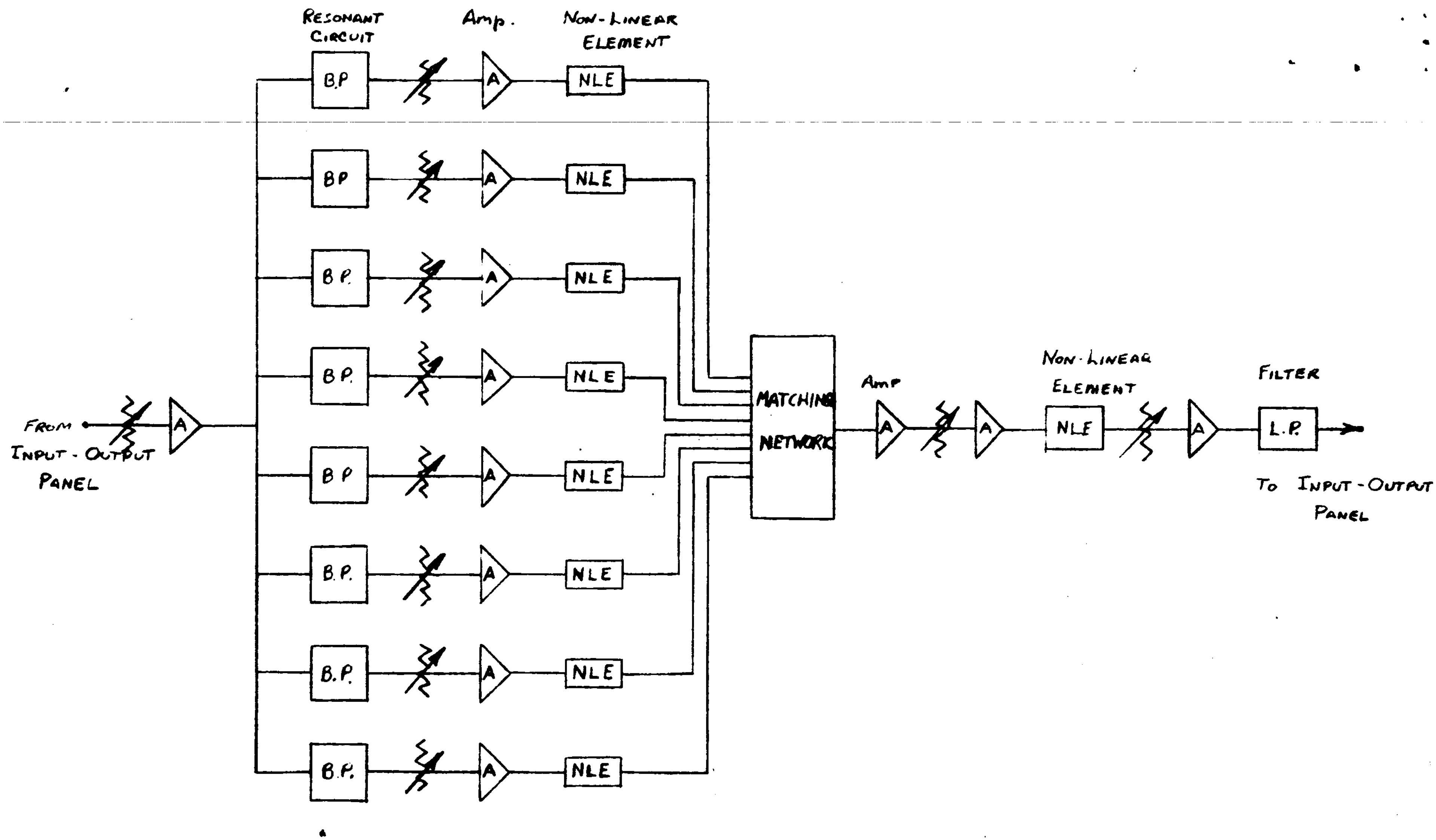

FIG. NO. 2 BLOCK DIAGRAM OF 10 CHANNEL CIRCUIT

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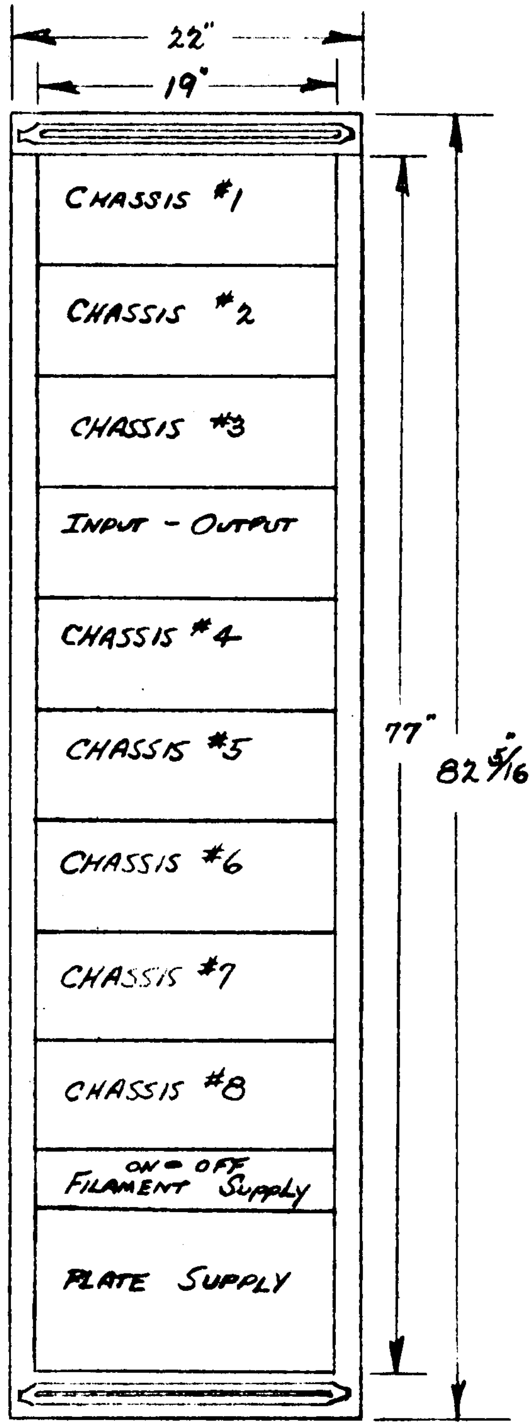

FIG. No. 3 80 CHANNEL NOISE REDUCER RACK

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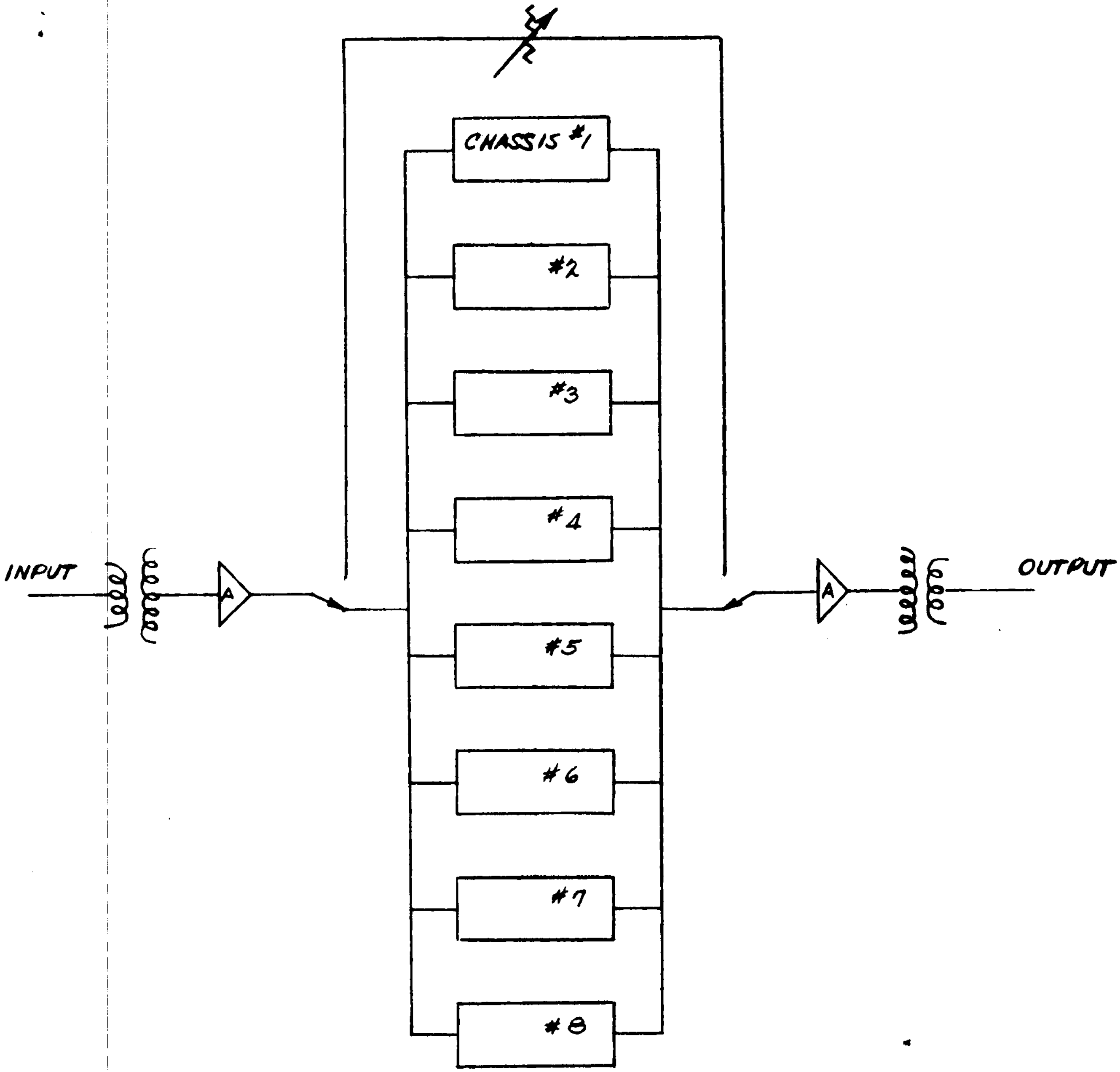

FIG No. 4 BLOCK DIAGRAM OF 80 CHANNEL NOISE REDUCTION CIRCUIT